

Comments on the possible discovery of the Higgs boson with mass ~ 160 GeV at the Tevatron

Engin ARIK¹, Saleh SULTANSOY^{2,3}

¹Boğaziçi University, Department of Physics, 34342 Bebek, Istanbul, TURKEY

²Gazi University, Department of Physics, 06500 Teknikokullar, Ankara, TURKEY

³Academy of Sciences, Institute of Physics, H. Cavid Avenue 33, Baku, AZERBAIJAN

Abstract

The consequences of the possible discovery of the Higgs boson with a mass around 160 - 180 GeV at the Tevatron are discussed.

Most probably, the search for the Higgs boson will be finalized within few years. Its discovery will close the large hole in the foundation of the Standard Model (SM) of elementary particles. At the end of 2000, just before the LEP collider was shut down, the four experiments (ALEPH, DELPHI, L3, OPAL) published their search results for the Higgs boson (H) signal in the process $e^+e^- \rightarrow ZH$ at centre-of-mass energies up to 209 GeV. The results reported a lower limit of 114.4 GeV on the SM Higgs boson mass with 95 % confidence level [1]. Currently, a fit to electroweak measurements gives an upper limit of 199 GeV to the preferred mass value [2], assuming 3 SM families.

Before the LHC data taking starts in 2007, the upgraded Fermilab Tevatron data may signal a discovery. Currently, the collected data amount to $\sim 1 \text{ fb}^{-1}$ per experiment which will double in a year. Recently, the two experiments CDF and D0 at the Tevatron have been searching for a signal in the channel

$$p\bar{p} \rightarrow H X \quad \text{with} \quad H \rightarrow WW^{(*)} \rightarrow l\nu l'\nu \quad (l, l' = e, \mu) . \quad (1)$$

The analyzed sample in the above channel corresponds to $\sim 320 \text{ pb}^{-1}$ for D0 and $\sim 180 \text{ pb}^{-1}$ for CDF [2]. In the Table below, we present the D0 results [3] together with the addition of the last column indicating the number of signal events expected with 4 SM families.

In the recent speculative ('provocative') comments [4] on D0 data [3], it was pointed out that the data can be interpreted as a clue relating to the Higgs boson with a mass of $\sim 160 \text{ GeV}$. Even though there were justified objections [5] to the way the data was interpreted, the aim of this exercise was to initiate more activity on the subject. In this study, we clarify our reasons in attracting attention to this topic and give some suggestions.

As seen in the Table, in the case of 3 SM families, this channel is not promising for the observation of a Higgs signal at the Tevatron. However, the Higgs boson can be discovered before the LHC starts, if the 4th SM family exists in nature.

Table : Number of signal and background events expected and number of events observed after all selections are applied. Only statistical uncertainties are given.

We have used an average enhancement factor of 8.5 for the last column.

$m_H \text{ (GeV)}$	$H \rightarrow WW^{(*)}$ 3 families	Background sum	Data	$H \rightarrow WW^{(*)}$ 4 families
100	0.007 ± 0.001	31.0 ± 2.8	25	0.06
120	0.11 ± 0.01	30.2 ± 2.5	23	0.09
140	0.33 ± 0.01	21.4 ± 1.6	21	2.80
160	0.54 ± 0.02	17.7 ± 1.0	20	4.60
180	0.36 ± 0.01	19.1 ± 1.0	20	3.06
200	0.17 ± 0.01	20.0 ± 1.1	16	1.45

The comparison of the data and the estimated background show a positive excess region around 160 GeV and deficit at 100, 120 and 200 GeV, which was the motivation for the comments in [4] where the statistical error on the data was not taken into account. The above mentioned excess and deficit are not statistically significant at this level of data.

The analysis of the present data sample (1 fb^{-1} per experiment) will improve the statistical significance of the above claim. Let us consider in detail

the case of 160 GeV Higgs at 2 fb^{-1} integrated luminosity. The expected number of signal (4 SM families) and background events will be $S \sim 29$ and $B \sim 111$ respectively, which gives a significance of $S/\sqrt{B} = 2.8$.

If the two experiments complete the analysis of the already collected data and join their results they will be able to clarify this issue, otherwise D0 will have an answer in the next year. In 2006 combined integrated luminosity will be 4 fb^{-1} and 160 GeV mass Higgs could be observed at the Tevatron with an evidence of $\sim 4\sigma$. Similar analysis can be extended to the other mass values. For example with 4 fb^{-1} 180 GeV mass Higgs could be observed with an evidence of $\sim 3\sigma$.

The discovery of the Higgs boson with $m_H = 160 - 180 \text{ GeV}$ at the Tevatron will change drastically the streamline of high energy. First of all, this will be an indirect manifestation of the 4^{th} SM family. In this case, the LHC will observe the 4^{th} family quarks directly before 2010. The preferable mass of the 4^{th} family fermions is approximately 600 GeV which will be a strong argument for the priority of the CLIC as a linear $e^+ e^-$ collider. The CLIC with $\sqrt{s} = 1 - 3 \text{ TeV}$ will discover the 4^{th} family leptons.

Secondly, this will discourage the SUSY community because the upper limit on the mass of the Higgs boson in SUSY is $\sim 130 \text{ GeV}$. The beauty of SUSY should be realized at the most fundamental, pre-preonic, level as we claimed in [6]. Indeed, the number of observable free parameters in MSSM is too large [7] to be realistic.

The LHC will touch the preonic level with large probability. Models with extra dimensions should also be realized at the most fundamental level therefore the chance that their predictions will be tested at the LHC is very small.

In conclusion, the existence of the 4^{th} SM family could be confirmed indirectly in the near future, if m_H is around 160 GeV.

Our suggestions for the Tevatron:

- The analysis of the H WW(*) need to be the top priority for both D0 and CDF experiments.
- D0 and CDF data need to be combined, which will correspond to approximately doubling of the integrated luminosity.
- A dedicated workshop on this issue before the end of the year will be very desirable.

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References

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